Lesson 8

Storage Devices

1-Hard Disk Drive Systems

- Hard disk is main storage device that is most commonly used to store all type of data as well as one of the most interesting components of computer.
- A hard disk drive is a sealed unit that a PC uses for nonvolatile data storage
- *Hard disk drive (HDD) systems (hard disks or hard drives) are used for permanent* storage and quick access.
- The hard disk drive system contains three critical components:

1. **Hard disk**
2. **Controller**
3. **Host adapter**

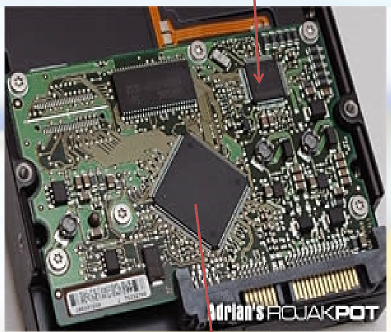
1-Hard disk

- This is the physical storage medium.
- Hard disk drive systems store information on small discs also called *platters, stacked* together and placed in an enclosure

2-Controller

The Motor Drive Controller

- This component controls the drive.
- The controller chip controls how the drive operates, sends signals to the various motors in the disk, and receives signals from the sensors inside the drive.
- Most of today's hard disk technologies incorporate the controller and drive into one enclosure.
- The most common and well-known of these are PATA and

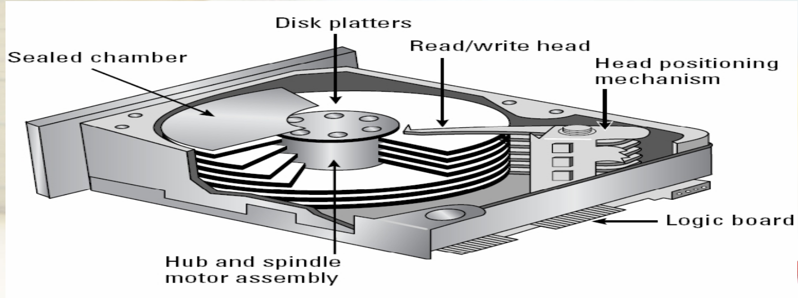


The Hard Disk Controller

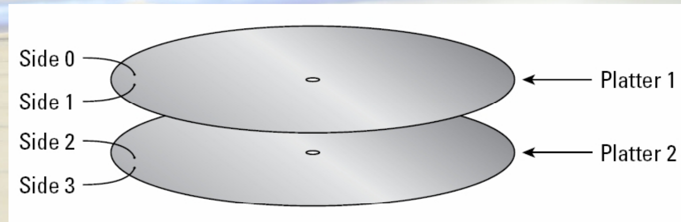

Spindle
Actuator Arm
Actuator

2-Platters

- Is physical object inside the hard disk that is responsible for storing the data.
- Every hard disk uses one or more (generally more than one) round, flat disks called platters, coated on both sides with a special media material designed to store information in the form of magnetic patterns.
- Each surface of each platter on the disk can hold billions of bits of data.

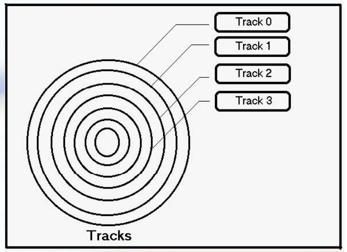


- Each platter has two sides for storing information, and each side of the platter has a unique ID.
- The ID for the first side of the first platter is 0, and each side increases by 1.



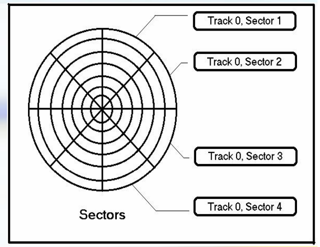
Tracks

- All information stored on a hard disk is recorded in tracks.
- The tracks are numbered, starting from 0, starting at the outside of the platter and increasing as you go in.
- tracks can store 100,000 or more bytes of data Therefore if we make a track the smallest unit of storage on the disk it will be the wastage of disk space, because by doing this the small files having the size less then 100000 bytes will waste the amount of space and generally it is quite possible to having a number of files in the disk which are much smaller than this size.



sectors

- Therefore, each track is broken into smaller units called sectors.
- The platter is divided into pie-shaped slices, called sectors.
- The size of each sector is 512 bytes i.e. a sector can hold 512 bytes of information.
- The sectors on a track are numbered starting with 1, unlike the heads or cylinders that are numbered starting with 0.



notes

Master Boot Record

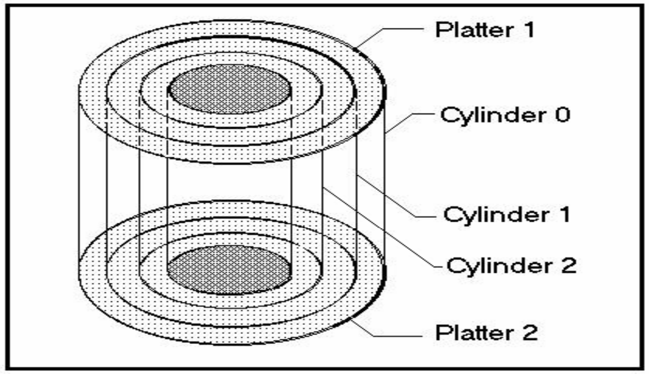
- The *Master Boot Record (MBR)* is the first sector on the first track of the first side of the first platter; it holds the operating system boot code that controls the loading of the operating system.
- The MBR also holds drive characteristics, such as the partition table.

Clusters "allocation units"

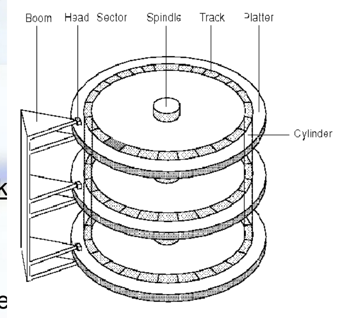
- A group of sectors makes up a *cluster, and a cluster is the allocation unit* for a file — meaning where a file is saved.
- When a partition is formatted, the file system determines the cluster size based on the partition size.
- Keep in mind that after a file has been saved to the cluster, no other file can occupy that cluster.
- For example, if you have a 32K cluster size and you save a 3K file to the hard disk, the file is saved to an empty cluster — but only 3K of that cluster is used, and the remaining 29K is empty.
- The remaining 29K is now considered unusable space; no other file can be saved to that unused 29K.

Cylinders

- A *cylinder consists of the same track on both sides of all the platters.*



3-Read/Write head



- Each platter of the hard disk uses two heads (except some special cases) to record and read data, one for the top of the platter and one for the bottom.
- The heads that access the platters are lock together on an assembly of head arms therefore all the heads move in and out together, so each head is always physically located at the same track number.
- This is the reason that it is not possible to have one head at track 0 and another at track 1,000.
- Because of this arrangement, often the track location of the heads is not referred to as a track number but rather as a cylinder number.

CHS

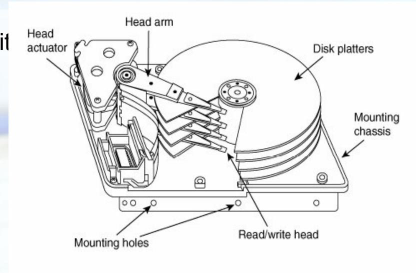
- If you know the number of cylinders, heads, and sectors per track, you can calculate the size of a disk.
- The formula to calculate the size of the disk is

number of cylinders × number of heads × number of sectors per track × 512 bytes per sector.

- **For example, if a drive has**
- 4,092 cylinders
- 16 heads,
- 63 sectors per track,
- the size of the disk would be 2,111,864,832 bytes(2.1GB).

4-Actuator Arm

- The actuator arm has multiple read/write heads on it

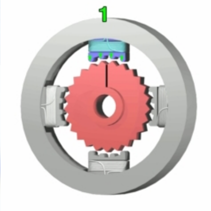


Head Actuator Mechanisms

- This refers to the device that physically moves the actuator arms.

1. Stepper motor actuators
2. Voice coil actuators

Stepper motor actuators

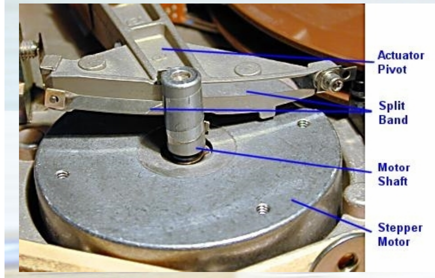


- A stepper motor is an electrical motor that can "step," or move from position to position, with mechanical detents or click-stop positions.
- It rotates when voltage is applied to their terminals
- The stepper motor can only take one step at a time and each step is the same size.
- Stepper motors can't position themselves between step positions; they can stop only at the predetermined detent positions
- As the drive platters heat and cool, they expand and contract, and the tracks on the platters move in relation to a predetermined track position.
- The stepper mechanism can't move in increments of less than a single track to correct for these temperature-induced errors. The drive positions the heads to a particular cylinder according to a predetermined number of steps from the stepper motor, with no room for nuance.

Voice coil actuators

- A voice coil actuator works by pure electromagnetic force.
- In a typical hard disk drive's voice coil system, the electromagnetic coil is attached to the end of the head rack and placed near a stationary magnet.
- No physical contact occurs between the coil and the magnet; instead, the coil moves by pure magnetic force.
- As the electromagnetic coils are energized, they attract or repulse the stationary magnet and move the head rack.
- Modern hard drives use a voice coil actuator, which controls the movement of a coil toward or away from a permanent magnet based on the amount of current flowing through it. This guidance system is called a servo.

Head Actuator Mechanisms



This refers to the device that physically moves the actuator arms.

Characteristic	Stepper motor actuators	Voice coil actuators
Relative access speed	Slow	Fast (much quieter)
Temperature sensitive	Yes (very)	No
Positionally sensitive	Yes	No
Preventive maintenance	Periodic reformat	None required
Relative reliability	Poor	Excellent
Automatic head parking	Not usually	Yes

PARKING OF RW HEAD

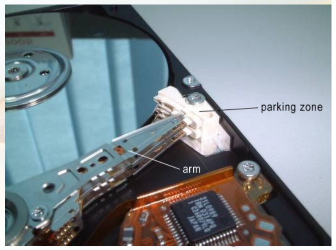
The heads in most hard disk drives do not (and should not!) touch the platters during normal operation.

A landing zone technology

- In most drives, when the drive is powered off, the heads move to the innermost cylinder, where they land on the platter surface.

Load/Unload technology

- When the computer is switched off, the head is usually pulled to a safe parking zone to prevent the head from scratching against the data zone on platter when the air bearing subsides.



- Older drives required manual head parking
- Modern drives automatically park the

Read/write process

- Platters are divided into 512-byte sectors.
- These sectors are the area on the platter that data is written to.
- The platters have a magnetic coating applied to them that is extremely sensitive to magnetism.
- While the platters spin, the read/write head moves from track to track until it reaches the desired track.
- Then it waits for the appropriate sector to move underneath it, at which time the read/write head is energized to apply a magnetic charge to the particles in the disk coating.
- This changes the particle binary state from zero to one, thus creating data.
- The same happens when the data needs to be read, the read/write head moves over the appropriate sector and reads the data that resides in the sector.

ATA

- The terms AT Attachment (ATA) and Integrated Device Electronics (IDE) are one and the same; both define a type of hardware interface that is commonly used to attach devices such as hard drives and CD-ROM drives to a computer system.

ATA1

- The ATA interface specified a cable (a 40-pin) and a built-in controller on the drive itself.
- ATA standard used the existing AT BIOS
- The ATA-1 standard defined that no more than two drives attach to a single IDE connector on a single ribbon cable.
- If you're making a hard drive standard, you must define both the method and the speed at which the data's going to move.
- ATA-1 defined two different methods,

(PIO) addressing		DMA mode.	
using programmed I/O		direct memory access	
PIO mode 0	3.3 MBps	Single word DMA mode 0:	2.1
PIO mode 1	5.2 MBps	Single word DMA mode 1:	4.2
PIO mode 2	8.3 MBps	Single word DMA mode 2:	8.3

- Cant recognize hard drives larger than 504 MB

- the original BIOS code found on computers was limited to being able to see only 1024 cylinders, 16 heads, and 63 sectors — which is a total drive size of 504MB (1024 × 16 × 63 × 512).

Table 5-1 BIOS Limit Example

	Cylinders	*Heads*	*Sectors*	*Total Size*
BIOS limit	**1024**	16	63	504MB
Hard drive (physical geometry)	16384	**4**	**63**	2.1GB
Detected	1024	4	63	132MB

ATA-2

Many people called these new features *Enhanced IDE (EIDE)*.

1-Higher Capacity with LBA *(ECHS)*

- *Logical Block Addressing* (LBA) and *Extended Cylinder/Head/Sector* (ECHS)
- LBA was developed by Western Digital while ECHS was Segate's solution to recognizing larger drives
- their purpose is. perform the same goal — they perform *sector translation;*
- sector translation is the hard drive controller lying to the BIOS about the drive geometry.
- The ATA specification was designed to have two geometries. The *physical geometry* defined the real layout of the CHS inside the drive.
- The *logical geometry* described what the drive told the CMOS.
- In other words, the IDE drive "lied" to the CMOS, thus sidestepping the artificial limits of the BIOS. When data was being transferred to and from the drive, the onboard circuitry of the drive translated the logical geometry into the physical geometry. This function was, and still is, called *sector translation.*

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LBA and ECHS

- An LBA enabled BIOS can recognize 1024 cylinders, 256 heads, and 63sectors — essentially being able to support more heads on the drive
- As a result, the drive lies to the BIOS by using a *translation factor* of usually 2, 4, 8, or 16.
- The physical dimensions of the drive are taken and manipulated by the translation factor to calculate the logical dimensions that are reported to the BIOS.
- In order to leverage larger size drives, your BIOS would have to

Table 5-2 LBA Enabled BIOS Translation Example

	Cylinders	*Heads*	*Sectors*	*Total Size*
BIOS limit	**1024**	16	63	504MB
LBA enabled BIOS limit	**1024**	256	63	8.4GB
Hard drive (physical geometry)	16384	**4**	**63**	2.1GB
Translation Factor	Divide by 16	Multiply by 16		
LBA Translated Geometry	**1024**	**64**	**63**	**2.1GB**

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2-Not Just Hard Drives Anymore: ATAPI

- ATA-2 added an extension to the ATA specification, called Advanced Technology Attachment Packet Interface (ATAPI), that enabled non-hard drive devices such as CD-ROM drives and tape backups to connect to the PC via the ATA controllers.

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3- More Drives with ATA-2

- support for two more ATA devices, for a maximum of four

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4- Increased Speed

(PIO) addressing		DMA mode.	
using programmed I/O		direct memory access	
PIO mode 3	11.1 MBps	Multiword DMA mode 0:	4.2
PIO mode 3	16.6 MBps	Multiword DMA mode 1:	13.3
		Multiword DMA mode 2:	16.6

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ATA-3

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1- S.M.A.R.T.

- ATA-3 came on quickly after ATA-2 and added one new feature called *Self-Monitoring, Analysis, and Reporting Technology* (*S.M.A.R.T.*, one of the few PC acronyms that requires the use of periods after each letter). S.M.A.R.T. helps predict when a hard drive is going to fail by monitoring the hard drive's mechanical components.
- only a few utilities can read the S.M.A.R.T. data

- Note
- ATA-3 standard did not enhance transfer speeds

2-Security function:

- The peripherals can be protected by a password added to the BIOS.
- When the computer is started, it verifies that the password encoded in the BIOS corresponds to the one stored on the drive.
- This allows you to prevent the drive from being used on a different computer.

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ATA-4

ATA/33

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1-Ultra-DMA

- ATA-4 introduced a new DMA mode called Ultra-DMA that is now the primary way a hard drive communicates with a PC. Ultra DMA uses DMA bus mastering to achieve far faster speeds than was possible with PIO or old-style DMA.

ATA-4 defined three Ultra DMA modes:

- Ultra DMA mode 0: 16.7 MBps
- Ultra DMA mode 1: 25.0 MBps
- Ultra DMA mode 2: 33.3 MBps
- **NOTE** Ultra DMA mode 2, the most popular of the ATA-4 DMA modes, is also called ATA/33

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2-INT13 Extensions

- The T13 folks said, “This isn’t *our* problem! It’s the ancient BIOS problem. You BIOS makers need to fix the BIOS!” And they did.
- In 1994, Phoenix Technologies (the BIOS manufacturer) came up with a new set of BIOS commands called *Interrupt 13 (INT13) extensions.*
- INT13 extensions broke the 8.4-GB barrier by completely ignoring the CHS values and instead feeding the LBA a stream of addressable sectors.
- The original ATA specification used a 28-bit addressing mode, allowing for the addressing of 2^{28} (268,435,456) sectors (blocks) of 512 bytes each, resulting in a maximum capacity of about 128 gigabytes
- 2^{28}*512 = 137 438 953 472 bytes
- 137 438 953 472/(1024*1024*1024)= 128 Gb
- The entire PC industry quickly adopted INT13 extensions and every system made since 2000–2001 supports INT13 extensions.

ATA-5

ATA66

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1-More Speed

- Ultra DMA mode 3: 44.4 MBps
- Ultra DMA mode 4: 66.6 MBps
- **NOTE** Ultra DMA mode 4, the most popular of the ATA-5 DMA modes, is also called ATA/66.

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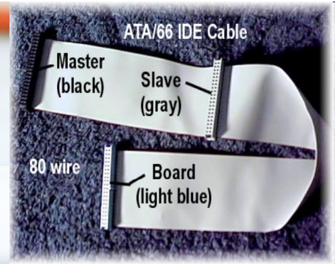
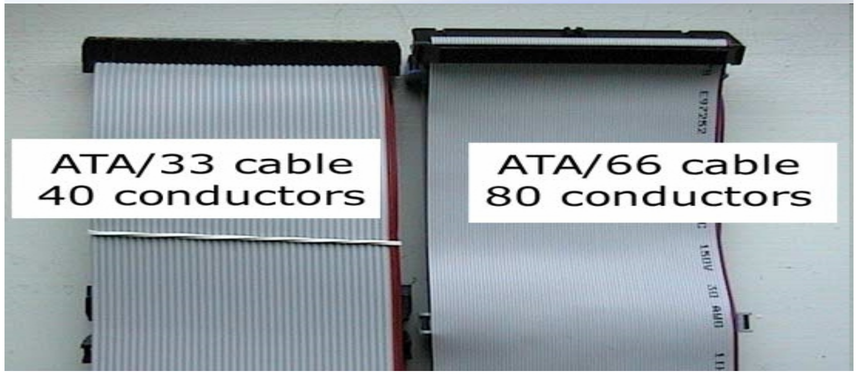
- Ultra DMA modes 4 and 5 ran so quickly that the ATA-5 standard defined a new type of ribbon cable of handling the higher speeds.





ATA-6

ATA/100,

1-More space

- when drives started hitting the 120-GB mark, the T13 committee adopted an industry proposal pushed by Maxtor (a major hard drive maker) called *Big Drive* that increased the limit to more than 144 petabytes (approximately 144,000,000 GB).
- T13 also thankfully gave the new standard a lesssilly name, calling it ATA-6.
- Big Drive was basically just a 48-bit LBA, supplanting the older 24-bit addressing of LBA and INT13 extensions.

More speed

- ATA-6 also introduced Ultra DMA mode 5, kicking the data transfer rate up to 100 MBps.
- Ultra DMA mode 5 is more commonly referred to as ATA/100, which requires the same 80-wire connectors as ATA/66.

ATA-7

1- last of the parallel ATA Ultra DMA modes ATA/133

- ATA-7 introduced the fastest and probably least adopted of all the ATA speeds, Ultra DMA mode 6 (ATA/133).
- There's a trend in the industry to color the controller connections on the hard drive red, although this is not part of the ATA-7 standard.

parallel ATA has problems.

- First, the flat ribbon cables impede airflow and can be a pain to insert properly.
- Second, the cables have a limited length, only 18 inches.
- Third, you can't hot-swap PATA drives. You have to shut down completely before installing or replacing a drive.
- Finally, the technology has simply reached the limits of what it can do in terms of throughput.

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2-new form of ATA called *serial ATA (SATA).*

- much thinner cabling
- SATA creates a point-to-point connection between the SATA device—hard disk, CD-ROM, CD-RW, DVD-ROM, DVD-RW, and so on—and the SATA controller.
- cables length(1 meter) instead of 18 inches.
- No master/slave concept. Each drive connects to one port, so no more daisy-chaining drives.
- no maximum number of drives—many motherboards are now available that support up to 8 SATA drives.
- data throughput theoretically up to 30 times faster than PATA
  - **SATA 1.5 Gbit/s (First generation)**
  - **SATA 3 Gbit/s (Second generation)**
  - **SATA 6 Gbit/s (Third generation)**

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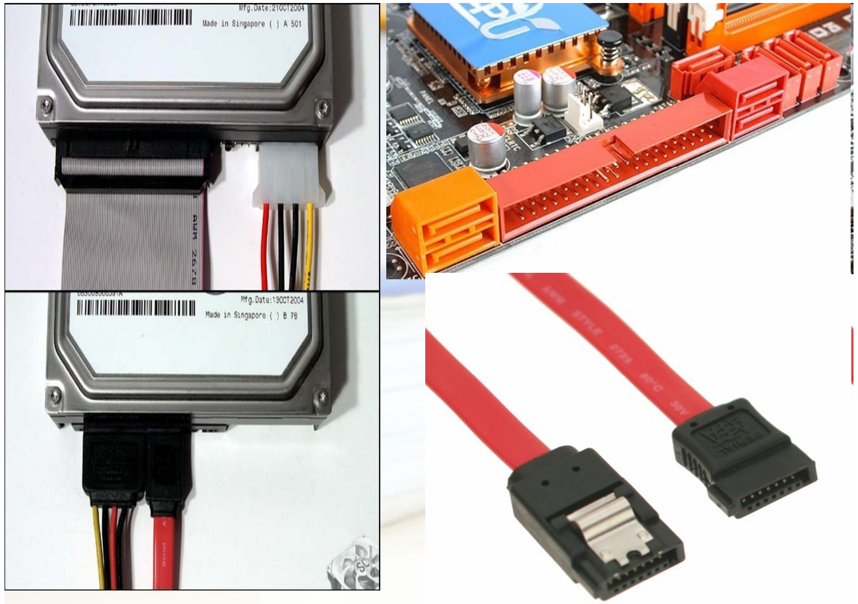


eSATA

- External SATA (eSATA) extends the SATA bus to external devices, as the name would imply.
- The eSATA drives use similar connectors to internal SATA, but they're keyed differently so you can't mistake one for the other.
- eSATA uses shielded cable lengths up to 2 meters outside the PC and is hot pluggable.
- requires its own power connector,

Name	bandwidth (Mbit/s)
eSATA	3,000
FireWire 800	786
FireWire 400	393
USB 2.0	480
USB 1.0	12

SATA (left) and eSATA (right) connectors

Performance

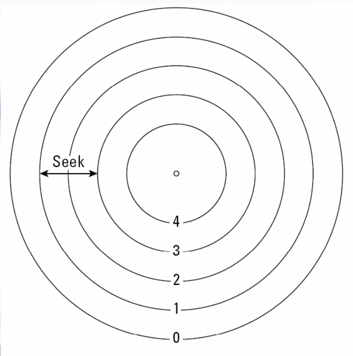
1. Spin speed
2. Seek time
3. Latency
4. Access time

1-Spin speed

- is the speed at which the platters spin, measured in rotations per minute, or rpm.
- The larger the rpm value, the faster the disk, which means less latency.

2-Seek time

- is the time it takes to move the read/write heads to the desired track.
- Seek time is a calculated <u>average</u> because the time it takes to move the desired track differs from one instance to another.
- For example, if the read/write heads are on Track 1, they will take longer to move to Track 12 than to Track 3.
- Seek time is measured in milliseconds, or one thousandth of a second



3-Latency

- is the time it takes for the appropriate sector to move under the read/write head.
- Latency is measured in milliseconds.

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4- Access time

- describes the overall speed of the disk.
- It is a combination of seek time and latency.
- The lower the access time, the better.

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